DESCRIPTION

CHANNEL SIMULATOR AND WIRELESS APPARATUS EVALUATION
METHOD

5   Technical Field

The present invention relates to a channel simulator
for simulating a wireless channel to evaluate a wireless
apparatus and a method of evaluating the wireless
apparatus.

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Background Art

Conventionally, in developing a cellular telephone,
a base station for the telephone, and MT and AP of wireless
LAN, there is needed an apparatus for simulating a wireless
15   channel as an environment for performance evaluation of
a development apparatus, i.e. a channel simulator.

By comparing transmission characteristics obtained
by providing signals transmitted from a development
apparatus with simulated fading and receiver noise using
20   a channel simulator with theoretical values or computer
simulation values, it is possible to judge whether the
development apparatus performs desired operation.
Further, by reproducing a channel state of a running
experimental course, it is possible to analyze a failure
25   of a development apparatus occurring under an actual
propagation environment. By thus using a channel
simulator, characteristic evaluations of a development

apparatus can be performed in a room with ease.

FIG.1 shows an example of a configuration of a conventional channel simulator. In channel simulator 10, a transmission signal output from a transmission system of a development apparatus 40 is passed through a multipath channel configured according to set parameters from control apparatus 30. At this point, a signal passed through each path is given the amplitude variation and phase variation (hereinafter, referred to as propagation path variations) simulating fading, weighted with a gain of each path to be added, and receiver noise is added to the resultant signal. The signal given the propagation path variations and receiver noise by channel simulator 10 is received and demodulated in reception system 50 of the development apparatus, and the demodulated signal is output to error rate measurement instrument 70. Thus, it is possible to evaluate performance of transmission system 40 and reception system 50 of the development apparatus by observing error rate measurement results obtained by adding various propagation path variations and receiver noise using channel simulator 10.

A specific configuration of channel simulator 10 will be described below. Channel simulator 10 is connected to transmission system 40 of the development apparatus comprised of digital baseband processing section (digital BB processing section) 41, analog

baseband processing section (analog BB processing section) 42 and radio circuit 43, while being connected to reception system 50 of the development apparatus comprised of radio circuit 53, analog BB processing section 52 and digital BB processing section 51. In addition, in FIG.1, each line represents two baseband signal lines comprised of an I channel (in-phase i.e. the real part of a complex number) and a Q channel (quadrature i.e. the imaginary part of the complex number), except lines for connecting between radio circuits 43 and 11 and between radio circuits 20 and 53.

Digital data generated in data generator 60 is input to channel simulator 10 via digital BB processing section 41, analog BB processing section 42 and radio circuit 43 of transmission system 40. Digital BB processing section 41 is a portion to perform digital modulation, spreading and other processing when transmission system 40 of the development apparatus is a CDMA (Code Division Multiple Access) transmission apparatus, while being a portion to perform digital modulation, inverse Fourier transform and other processing when the system 40 is an OFDM transmission apparatus. Analog BB processing section 42 is a digital/analog conversion circuit, and radio circuit 43 is a portion to perform upconverting, signal amplification, etc.

Channel simulator 10 has radio circuit 11 that performs processing inverse to that in radio circuit 43,

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i.e. processing such as downconverting, and analog BB processing section 12 comprised of an analog/digital conversion circuit, and converts a signal from transmission system 40 into a digital baseband signal
5   using radio circuit 11 and analog BB processing section 12.

The digital baseband signal is input to multipath signal generating section 13 comprised of shift register 14 and selector 15, and becomes a multipath signal in
10   multipath signal generating section 13. More specifically, shift register 14 shifts the digital baseband signal input thereto by time obtained by dividing the maximum delay time of a path by a sampling cycle of analog BB processing section 12.

15   Selector 15 selects signals corresponding to the number of paths from among signals output from each shift stage of shift register 14. At this point, multipath instruction signal S1 indicative of the number of paths and delay time of each path designated from control
20   apparatus 30 is input to multipath generating section 13, and shift register 14 and selector 15 operate based on multipath instruction signal S1. In this way, selector 15 in multipath generating section 13 outputs a signal corresponding to each path under multipath
25   environments.

The signal corresponding to each path is output to a respective one of complex multipliers A1 to Ak in

instantaneous variation (Rayleigh fading) adding section 16. Complex multipliers A1 to Ak are supplied with complex gaussian noise generated by band-limited complex gaussian noise generating sections (LGN) D1 to Dk,

5 respectively. In addition, each of band-limited complex gaussian noise generating sections (LGN) D1 to Dk is comprised of a white gaussian noise generating section and a Doppler filter, and generates white gaussian noise limited in band to a range of maximum Doppler frequency

10 S2 input from control apparatus 30. By this means, complex multipliers A1 to Ak output respective signals of paths each provided with the instantaneous variation.

The signals of paths provided with instantaneous variations are output to a plurality of complex

15 multipliers, B1 to Bk, forming short-term interval variation adding section 17. Each of complex multipliers B1 to Bk is supplied with complex gain S3 corresponding to the respective path designated from control apparatus 30, and thus, short-term interval variation adding

20 section 17 outputs a signal of each path provided with shadowing and distance variation. By this means, in channel simulator 10, for each path, a signal is formed which is provided with the instantaneous variation, shadowing and distance variation designated from control

25 apparatus 30, and the signal of each path is all added in adders C1, C2,..., whereby a multipath signal is formed in which are reflected propagation path variations.

Channel simulator 10 has receiver noise adding section 18 that adds receiver noise to the multipath signal. Receiver noise adding section 18 adds white noise of noise level S4 designated from control apparatus 30 to the

5   multipath signal.

Actually, receiver noise adding section 18 adjusts the white noise generated in white noise generating section 21 to noise level S4 in amplifier 22, adds the adjusted noise to the multipath signal in adder 23, and

10   thereby adds receiver noise. In simulating a single-path channel, multipath signal generating section 13 generates only a signal of a single path, and the signal is given receiver noise in adder 23 without being given the fading variation in complex multipliers A1 and B1.

15   Analog BB processing section 19 and radio circuit 20 respectively have the same configurations as those of analog BB processing section 42 and radio circuit 43 of transmission system 40, convert a digital BB signal given the propagation path variations and receiver noise,

20   and then, perform radio processing such as upconverting and amplification on the converted signal.

An output signal of channel simulator 10 is input to radio circuit 53 of development apparatus (reception system) 50. Radio circuit 53 has an AGC (Automatic Gain

25   Control) circuit and AFC (Automatic Frequency Control) circuit, and compensates for carrier frequency offset between transmission and reception and input level

variations. The signal having undergone analog/digital conversion in analog BB processing section 52 is output to digital BB processing section 51.

Digital BB processing section 51 is a portion to perform digital demodulation, despreading and other processing when development apparatus (reception system) 50 is a CDMA (Code Division Multiple Access) reception apparatus, while being a portion to perform digital demodulation, Fourier transform and other processing when the system 50 is an OFDM reception apparatus. The signal processed in digital BB processing 51 is input to error rate measurement instrument 70, and error rate measurement instrument 70 measures a channel error rate of the signal.

Thus, in channel simulator 10, simulated multipath, fading variation and receiver noise assumed to occur on transmission channels are added to radio signals obtained in transmission system 40 of the development apparatus, thus obtained signals are input to reception system 50 of the development apparatus, and error rate characteristics of signals processed in reception system 50 are measured, thereby evaluating transmission characteristics of transmission system 40 and reception system 50.

As described above, in the conventional channel simulator, in such a state that the transmission system and reception system of a development apparatus have been

completed to some extent, a radio signal output from the transmission system is given the simulated propagation path variations and receiver noise, and then, supplied to the reception system as a radio signal, and an error

5   rate of data obtained by reception processing in the reception system is measured, whereby performance of the development apparatus is evaluated.

Thus, the conventional channel simulator is predicted on that the development apparatus has been

10   completed to such a state that analog baseband processing sections 42 and 52 and radio circuits 43 and 53 are operable, as well as digital baseband processing sections 41 and 51. In particular, unless development of radio circuit 53 of reception system 50 proceeds to such an extent that

15   the circuit is operable, it is not possible to perform AGC and AFC, and accurate performance evaluations cannot be carried out.

Therefore, it is not possible to check the operation of digital baseband processing sections 41 and 51

20   performing central processing until completion of radio circuits 43 and 53 (particularly, radio circuit 53 of the reception system 50), and there arises a problem that efficiency in development deteriorates corresponding to waiting for such completion.

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Disclosure of Invention

It is an object of the present invention to provide

a channel simulator and wireless apparatus evaluation method enabling transmission characteristics of a digital baseband processing section to be evaluated alone with excellence, irrespective of development of a radio

5 circuit.

The object is achieved by providing a channel simulator with a digital signal interface to input a digital baseband signal of a development apparatus, and providing the digital baseband signal with receiver noise

10 simulating the SNR (Signal-to-Noise Ratio) variation due to fading while keeping an entire signal level constant in single-path channel simulation. Further, in multipath channel simulation, the object is achieved by providing respective signals of paths with only amplitude

15 variations due to fading to combine, and keeping a level of the path-combined signal constant to output.

Brief Description of Drawings

FIG.1 is a block diagram illustrating a

20 configuration of a conventional channel simulator;

FIG.2 is a block diagram illustrating a configuration of a channel simulator according to Embodiment 1 of the present invention;

FIG.3 is a block diagram illustrating a

25 configuration of a band-limited complex gaussian noise generating section (LGN);

FIG.4(A) is a signal waveform chart of a radio signal

prior to noise addition;

FIG.4(B) is a signal waveform chart illustrating a general relationship between a signal level and noise level of a radio signal;

5   FIG.4(C) is a signal waveform chart illustrating a relationship between a signal level and noise level of a radio signal according to Embodiment;

FIG.5 is a block diagram illustrating a configuration of a channel simulator according to 10   Embodiment 2 of the present invention;

FIG.6 is a block diagram illustrating a configuration of a transmission analog adjusting section;

FIG.7 is a block diagram illustrating a configuration of a pseudo power amplifier (PA);

15   FIG.8 is a block diagram illustrating a configuration of a reception analog adjusting section;

FIG.9 is a diagram illustrating a model of how to add receiver noise on a single-path channel described in Embodiment 1; and

20   FIG.10 is a diagram illustrating another example of how to add receiver noise on a single-path channel.

Best Mode for Carrying Out the Invention

In this Embodiment, a channel simulator is provided 25   with a digital signal interface to input a digital baseband signal of a development apparatus, and the digital baseband signal is given receiver noise simulating the

SNR (Signal-to-Noise Ratio) variation due to fading with an entire signal level kept constant in single-path channel simulation, while in multipath channel simulation, respective signals of paths are given only amplitude

5   variations due to fading and combined to be output with a level of the path-combined signal kept constant. By this means, even if a radio circuit having AFC and AGC has not been completed, it is possible to simulate channel characteristics of a digital baseband processing section

10   at the stage where only the digital baseband processing section has become operable, and it is thereby possible to improve efficiency in development of the wireless apparatus.

In simulating characteristics on a single-path

15   channel, as a constitution to add receiver noise simulating the SNR variation due to fading while keeping a signal level of a digital baseband signal constant, it is considered adding to the digital baseband signal noise of a level corresponding to a level obtained by

20   dividing a noise level by a fading variation value.

Further, in simulating characteristics on a multipath channel, a constitution is considered where multipath signals are formed from the digital baseband signal, respective signals of paths of multipath signals

25   are each given a fading variation, receiver noise is added to a signal obtained by combining the signals, and gain is controlled to keep the signal level almost constant.

Embodiments of the present invention will specifically be described below with reference to accompanying drawings.

(Embodiment 1)

5   FIG.2 illustrates a configuration of a channel simulator according to Embodiment 1 of the present invention, where the same sections as in FIG.1 are assigned the same reference numerals as in FIG.1.   In addition, descriptions are omitted on the same sections as in FIG.1.

10   Further, as in FIG.1, each line represents two baseband signal lines comprised of an I channel (in-phase i.e. the real part of a complex number) and a Q channel (quadrature i.e. the imaginary part of the complex number), except lines for output signals from radio circuits 43

15   and 20.

In channel simulator 100, switch SW1 is provided between radio circuit 11 and analog BB processing section 12, while switch SW2 is provided between analog BB processing section 12 and multipath signal generating

20   section 13.   By this means, in channel simulator 100, an output signal from digital BB processing section 41 of transmission system 40 can directly be input via switch SW2, while an output from analog BB processing section 42 of transmission system 40 can directly be input via

25   switch SW1.

As a result, in channel simulator 100, even if development of radio circuit 43 and analog BB processing

section 42 has not been completed to be operable, by directly inputting an output signal of digital BB processing section 41 to multipath signal generating section 13 and subsequent circuits via switch SW2, it

5 is possible to evaluate channel characteristics of digital BB processing section 41 independently.

Further, even if development of radio circuit 43 has not been completed to be operable, by inputting an output signal of analog BB processing section 42 via switch

10 SW1, it is possible to evaluate channel characteristics of digital BB processing section 41 and analog BB processing section 42 except radio circuit 43.

Channel simulator 100 has instantaneous variation adding section 101 that adds an instantaneous variation

15 (Rayleigh fading) to an output signal from multipath signal generating section 13, short-term interval variation adding section 102 that adds shadowing and distance variation, receive noise adding section that adds receiver noise such as thermal noise in a receiver,

20 and automatic gain control section 104 that performs gain control on the multipath signal to keep the signal level almost constant.

In instantaneous variation adding section 101, in simulating a multipath channel, a plurality of complex

25 multipliers, A1 to Ak, complex-multiplies signals of paths by band-limited white gaussian noise generated in band-limited complex gaussian noise generating sections

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(LGN) E1 to Ek, and thereby adds instantaneous variations
to the signals of the paths, respectively.

Further, switch (SW) 105 is provided between
band-limited complex gaussian noise generating section
E1 and complex multiplier A1 in instantaneous variation
adding section 101, and either the band-limited white
gaussian noise or "1" is selectively input to complex
multiplier A1.

Actually, in simulation of multipath channel,
switch 105 provides the band-limited white gaussian noise
to complex multiplier A1 from band-limited complex
gaussian noise generating section E1, while providing
a value of "1" to divider 106 of receiver noise adding
section 103. Meanwhile, in simulation of single-path
channel, switch 105 provides a value of "1" to complex
multiplier A1, while providing the band-limited white
gaussian noise to divider 106 of receiver noise adding
section 103.

FIG.3 illustrates a configuration of each of
band-limited complex gaussian noise generating sections
E1 to Ek. Configurations of band-limited complex
gaussian noise generating sections E1 to Ek are basically
the same as one another, except instantaneous variation
initial value S10B which is provided from control
apparatus 110 to white gaussian noise generating section
(WGN) 121 and varies for each path.

Band-limited complex gaussian noise generating

sections E1 to Ek generate white gaussian noise corresponding to instantaneous variation initial value S10B which is provided from control apparatus 110 via white gaussian noise generating section 121. In addition,

5   white gaussian noise generating section 121 generates white gaussian noise of each of the I channel and Q channel (i.e. complex white gaussian noise), and also in subsequent circuits, the complex white gaussian noise is processed.

10   Doppler filter 122 limits the band of the white gaussian noise corresponding to maximum Doppler frequency fD from control section 110, and outputs band-limited white gaussian noise to phase variation ON/OFF section 123.

15   Phase variation ON/OFF section 123 controls ON/OFF of phase variation in the band-limited gaussian noise, corresponding to phase variation ON/OFF designation signal S10C from control section 110. More specifically, when receiving phase variation ON/OFF designation signal

20   S10C for designating ON of phase variation, the section 123 outputs the band-limited complex gaussian noise from Doppler filter 122 without processing the noise as an instantaneous variation value.

In contrast thereto, when receiving phase variation

25   ON/OFF designation signal S10C for designating OFF of phase variation, the section 123 obtains variation value envelop amplitude $\sqrt{(I^2+Q^2)}$ of I channel and Q channel

band-limited gaussian noise, and outputs the obtained
variation value envelop amplitude as signals of the I
channel and Q channel. In other words, the section 123
forms the band-limited complex gaussian noise of the I
channel and Q channel with the same level as an
instantaneous variation value, thereby adding only the
level variation without adding the phase variation in
complex multipliers A1 to Ak.

In channel simulator 100, short-term interval
variation adding section 102 is also capable of
selectively adding either a short-term interval variation
that does not cause a phase variation or short-term
interval variation that causes a phase variation. More
specifically, in the case of adding the short-term
interval variation that does not cause the phase variation,
control apparatus 110 outputs complex gain signal S11
such that the I channel and Q channel have the same values.
In the case of adding the short-term interval variation
that causes the phase variation, control apparatus 110
outputs complex gain signal S11 such that the I channel
and Q channel have different values.

In this way, using instantaneous variation adding
section 101 and short-term interval variation adding
section 102, channel simulator 100 is capable of
selectively providing the digital baseband signal with
the instantaneous variation without the phase variation,
instantaneous variation with the short-term interval

variation or phase variation, and short-term interval
variation.

Actually, when development of radio circuit 53 is
not completed, since phase compensation cannot be carried
out, the digital baseband signal is provided with the
instantaneous variation without the phase variation, and
short-term interval variation. In contrast thereto,
when development of radio circuit 53 is completed, phase
compensation can be performed in radio circuit 53, and
therefore, the digital baseband signal is provided with
the instantaneous variation with the phase variation,
and short-term interval variation.

At the time of simulation in multipath channel, in
receiver noise adding section 103, a value of "1" is input
to divider 106 from switch 105, and therefore, noise level
S4 designated from control apparatus 110 becomes a control
gain of amplifier 22 without any processing. By this
means, the white noise generated in white noise generating
section (WGN) 21 becomes a level corresponding to noise
level S4, and supplied to adder 23. In other words, in
simulation of multipath channel, adder 23 adds the white
gaussian noise of the level designated by noise level
S4 as receiver noise.

In contrast thereto, at the time of simulation in
single-path channel, in receiver noise adding section
103, divider 106 receives as its input band-limited
complex gaussian noise generated in band-limited complex

gaussian noise generating section E1 via switch 105. Divider 106 divides noise level S4 by the band-limited complex gaussian noise (actually, envelop amplitude value of the band-limited white gaussian noise). The quotient

5   is input to amplifier 22, as a control signal, which varies the amplitude of the white noise from white noise generating section (WGN) 21. By this means, as shown in FIG.4(c), adder 23 outputs such a signal that the signal level is constant and the SNR variation due to fading

10   is simulated.

The reason will be described below why receiver noise adding section 103 executes such processing. On an actual single-path channel, a radio signal as shown in FIG.4(A) is given receiver noise N as shown in FIG.4(B).

15   Position P1 where SNR is good and position P2 where SNR is poor appear in the received signal. Error rate characteristics are naturally poorer in the position where SNR is poor than in position P1 where SNR is good, due to quantization error, etc.

20   Receiver noise adding section 103 adds the SNR variation due to the receiver noise, while keeping the signal level constant. Therefore, receiver noise adding section 103 divides noise level S4 by the envelop amplitude of the band-limited white gaussian noise, and adds a value

25   obtained by multiplying the quotient by the white gaussian noise to a baseband signal. It is thus possible to simulate a signal with the same SNR as that of the signal

(FIG.4(B)) to which the receiver noise is added subsequent to fading, using the signal (FIG.4(C)) with the constant signal level. For example, positions P3 and P4 in FIG.4(C) respectively have the same SNR as that in corresponding positions in FIG.4(B), P1 and P2.

In addition, as in instantaneous variation adding section 101 and short-term interval variation adding section 102, receiver noise adding section 103 is capable of selectively providing the digital baseband signal with gaussian noise that does not cause the phase variation or gaussian noise that causes the phase variation. The case of not causing the phase variation as described above can be implemented with ease by making the envelop amplitude of the I channel and Q channel the same.

Thus, receiver noise adding section 103 is provided and adds the receiver noise which simulates the SNR variation due to fading with the entire signal level held constant in simulating a single-path signal, whereby it is possible to measure single-path channel characteristics of digital BB processing section 41 with excellence even when AGC of radio circuit 53 is not available (i.e. radio circuit 53 is not completed).

Automatic gain control section 104 does not operate in simulation of single-path channel, while operating only in simulation of multipath channel. Actually, in simulation of single-path channel, AGC section 108 receives as its input target level S12 for instructing

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to always set a gain of amplifier 107 at "1" from control
apparatus 110, whereby automatic gain control section
104 does not perform AGC processing on the digital baseband
signal of single-path, and outputs the signal without

5   any processing. The reason why the automatic gain
control processing is not performed on a single-path
signal is because the single-path signal is not provided
with the level variation in prior circuits, and only
provided with the SNR variation in receiver noise adding

10   section 103. However, automatic gain control section
104 does not operate to adjust the variation due to fading
or noise, and may make a gain adjustment to set the constant
level of a signal output from adder 23 at a target level.

In contrast thereto, at the time of simulation of

15   multipath channel, in automatic gain control section 104,
control apparatus 110 inputs target level S12 to AGC
section 108, and AGC section 108 thereby sets a difference
value between target level S12 and an output signal of
amplifier 107 as an amplification value of amplifier 107.

20   As a result, automatic gain control section 104 is capable
of generating a multipath signal with a constant value
of target level S12 by performing simplified digital gain
control processing.

The reason why it is necessary to perform gain

25   control on a multipath signal is because the multipath
signal resulting from addition by adder C1 is obtained
by adding respective signals of paths each provided with

the level variation independently of one another, and it is assumed that the level variation occurs in the digital baseband signal. In consideration thereof, the gain control section 104 executes the simplified digital

5   gain control processing to make the level of a multipath signal constant, and it is thereby possible to prevent a bit from being lost in AD conversion in the reception system of the development apparatus even when radio circuit 53 is not completed and the AGC processing cannot

10   be carried out. As a result, it is possible to evaluate channel characteristics on a multipath channel with excellence based on the digital baseband signal of digital BB processing section 41.

In the aforementioned constitution, when

15   development of digital BB processing sections 41 and 51 has been completed to the stage in which the sections are operable, channel simulator 100 receives an output signal of digital BB processing section 41 from switch SW2, and performs a simulation of single-path channel

20   and a simulation of multipath channel separately on the digital baseband signal.

In performing the simulation of a single-path channel, multipath signal generating section 13 forms a single-path digital baseband signal, and inputs the

25   signal to receiver noise adding section 103 via complex multipliers A1 and B1 and adder C1. At this point, neither instantaneous variation adding section 101 (complex

multiplier A1) nor short-term interval variation adding section 102 (complex multiplier B1) adds the phase variation or level variation to the single-path signal.

Receiver noise adding section 103 divides noise level S4 by the envelop amplitude of the band-limited white gaussian noise, adds the white gaussian noise multiplied by the quotient to the baseband signal, and thus provides the signal with the same SNR variation as that caused by fading as the receiver noise without adding the vibration variation nor phase variation. Thus, the digital baseband signal of the constant signal level only provided with the SNR variation is input to digital BB processing section 51 via switch SW4.

Meanwhile, in simulating a multipath channel, multipath signal generating section 13 forms a number of multipath signals with delay time where the number and the delay time is designated by control apparatus 110, and outputs respective signals of paths to complex multipliers A1 to Ak of corresponding rows. Then, instantaneous variation adding section 101 multiplies the signal of each path by the band-limited complex gaussian noise such that only the level variation occurs without the phase variation occurring, i.e. band-limited complex gaussian noise with I and Q components of the same level, and thus adds the instantaneous variation. Short-term interval variation adding section 102 adds complex gain such that only the level variation occurs

without the phase variation occurring to the signal of each path given the instantaneous variation.

Respective signals of paths thus given only level variations are all added in adders C1 to C(k-1), and given

5   white noise of designated noise level S4 in receiver noise adding section 103 as the receiver noise. The multipath signal given the receiver noise is made almost constant in signal level in a subsequent section, automatic gain control section 104.

10   Thus, in either a simulation of signal-path channel or a simulation of multipath channel, channel simulator 100 is capable of forming a signal of almost constant signal level provided with only the SNR variation without the phase variation. As a result, it is possible to

15   excellently evaluate channel performance of digital BB processing sections 41 and 51 without waiting for development of radio circuit 53 having an AGC circuit and AFC circuit.

Actually, in developing digital BB processing

20   sections 41 and 51, there are many cases that development can be advanced smoothly by first evaluating characteristics on a single-path channel, and then evaluating characteristics on a multipath channel. In this Embodiment, evaluations can be carried out on the

25   single-path channel and multipath channel separately, and it is thus possible to further increase efficiency in development.

In channel simulator 100, when development of analog BB processing sections 42 and 52 has been completed, an output signal of analog BB processing section 42 of transmission system 40 is input via switch SW1, while

5   an output signal of analog BB processing section 19 is input to analog BB processing section 52 of reception system 50 via switch SW3. It is thereby possible to evaluate performance of a combination of digital BB processing sections 41 and 51 and analog BB processing

10   sections 42 and 52.

Further, in channel simulator 100, when development of radio circuits 43 and 53 has been completed in addition to analog BB processing sections 42 and 52, an output signal of radio circuit 43 of transmission system

15   40 is input to radio circuit 11, while an output signal of radio circuit 20 is input to radio circuit 53 of reception system 50. It is thereby possible to evaluate performance of a combination of digital BB processing sections 41 and 51, analog BB processing sections 42 and

20   52 and radio circuits 43 and 53.

In addition, at the stage where radio circuits 43 and 53 are connected, since AGC function and AFC function operate by radio circuit 53, it may be possible that each of complex multipliers A1 to Ak and B1 to Bk multiplies

25   a noise component such that envelop amplitude differs between the I channel and Q channel and complex gain so as to provide a digital baseband signal with a phase

variation. Further, receiver noise adding section 103 and automatic gain control section 104 may be switched to OFF.

According to the aforementioned constitution, an
5   output signal of digital baseband processing section 41 is directly input, and receiver noise simulating the SNR variation due to fading is added with the entire signal level kept constant in single-path channel simulation, while respective signals of paths are provided with only
10   amplitude variations due to fading to be combined with a combined-path signal level kept constant in multipath channel simulation. It is thereby possible to evaluate channel performance of digital baseband processing section 41 without waiting for development of radio
15   circuit 53, i.e. without the AGC circuit and AFC circuit in reception system 50. As a result, it is possible to improve efficiency in development of the wireless apparatus.

The AGC circuit is to form suitable reception
20   amplitude at the point of AD conversion input so as to prevent SN deterioration due to a quantization error. However, it is difficult to ideally operate the circuit under fading because of imperfection in the circuit and control. In an extreme case, the circuit adds an
25   unnecessary amplitude variation. The method of adding variation noise proposed in this Embodiment dose not cause such deterioration, and therefore, enables acquisition

of performance in good agreement with theoretical values.

In this Embodiment, in evaluating performance on a single-path channel of a wireless apparatus, a case is described of using receiver noise adding means comprised of band-limited complex gaussian noise generating section (LGN) E1, switch (SW) 105, white gaussian noise generating section (WGN) 21, amplifier 22, adder 23 and divider 106. However, the receiver noise adding means of the present invention is not limited to the aforementioned case, and it is only required to add receiver noise simulating the SNR variation due to fading while keeping the entire signal level constant. For example, a constitution may be applied as in other Embodiment described below.

(Embodiment 2)

FIG.5 illustrates a configuration of a channel simulator according to Embodiment 2 of the present invention, where the same sections as in FIG.2 are assigned the same reference numerals as in FIG.2. Channel simulator 200 of this Embodiment has the same configuration as that of channel simulator 100 of Embodiment 1 except transmission analog adjusting section 201 being provided before multipath signal generating section 13 and reception analog adjusting section 202 being provided after automatic gain control section 104.

By this means, in channel simulator 200, an output signal of digital BB processing section 41 is input via

transmission analog adjusting section 201, the same

channel simulation as in Embodiment 1 is performed on

the signal processed in transmission analog adjusting

section 201, and the signal subjected to the same channel

5   simulation as in Embodiment is processed in reception

analog adjusting section 202 and then, output to digital

BB processing section 51 of reception system 50.

      Transmission analog adjusting section 201 has a

digital circuit configuration as shown in FIG.6,

10   implements simulations of the function of radio circuit

43 corresponding to various set values S20A to S20I input

from control apparatus 110, and adds simulated signal

deterioration assumed to occur in radio circuit 43 to

the digital baseband signal.

15   Reception analog adjusting section 202 has a digital

circuit configuration as shown in FIG.8, implements

simulations of the function of radio circuit 53

corresponding to various set values S22A to S22H input

from control apparatus 110, and adds simulated signal

20   deterioration assumed to occur in radio circuit 53 to

the digital baseband signal.

      By this means, in channel simulator 200, even if

development of radio circuit 43 of transmission system

40 and radio circuit 53 of reception system 50 has not

25   been completed, it is possible to add signal deterioration

assumed to occur in radio circuits 43 and 53 to the digital

baseband signal to evaluate performance of digital BB

processing sections 41 and 51.

As a result, it is possible to evaluate channel characteristics of digital BB processing sections 41 and 51 including appropriateness between digital BB

5 processing sections 41 and 51 and radio circuits 43 and 53. Further, it is possible to beforehand measure an extent of deterioration to occur in radio circuits 43 and 53 subsequently developed with the performance of digital BB processing sections 41 and 51 meeting a desired

10 value.

Configurations of transmission analog adjusting section 201 and reception analog adjusting section 202 will specifically be described below. As shown in FIG.6, in transmission analog adjusting section 201, an output

15 signal from digital BB processing section 41 is input to gain unbalance generating section 210. Gain unbalance generating section 210 amplifies the I channel signal and Q channel signal of the digital baseband signal independently, and thereby generates a gain difference.

20 DC offset adding section 211 increases or decreases each of the I channel signal and Q channel signal by a constant value, and thereby adds the DC offset.

Frequency offset · phase offset adding section 212 adds the frequency offset and phase offset assumed to

25 occur in radio circuit 43 to the I channel signal and Q channel signal. Actually, frequency offset · phase offset adding section 212 is comprised of a complex

multiplier which multiplies each channel signal by variation amount cos $\theta 1$ or sin $\theta 2$ respectively corresponding to instantaneous phase $\theta 1$ or $\theta 2$.

In other words, the I channel signal is multiplied by variation amount cos $\theta 1$, while the Q channel signal is multiplied by variation amount sin $\theta 2$. Herein, instantaneous phases $\theta 1$ and $\theta 2$ being constant means only adding the phase offset, while instantaneous phases $\theta 1$ and $\theta 2$ varying with time means adding the frequency offset in addition to the phase offset.

In obtaining instantaneous phases $\theta 1$ and $\theta 2$, transmission analog adjusting section 201 calculates a phase rotation amount per sample from frequency offset set value S20E in phase increment calculating section 215 to output to mod 2π calculating circuits 217 and 219. At this point, to add deterioration in orthogonality between the I channel signal and Q channel signal, adder 218 adds orthogonality deterioration amount S20F to a phase rotation amount of the Q channel signal.

A phase of the last sample is input to adder 216. The phase of the last sample is calculated by Z-1 calculating circuit 222 performing computation based on an initial phase (i.e. phase offset) S20D and the phase of the last sample. Adder 216 adds the phase rotation amount corresponding to one sample calculated in phase increment calculating circuit 215 to the phase of the last sample, and thereby obtains a phase rotation amount

of a current sample.

Thus, by repeating a processing loop of adder 216, mod 2π calculating circuit 217 and Z-1 calculating circuit 222, I channel instantaneous phase $\theta 1$ provided with the phase offset and frequency offset is calculated for each sample, and Q channel instantaneous phase $\theta 2$ is calculated by adding the deterioration amount of orthogonality to I channel instantaneous phase $\theta 1$.

Then, frequency offset · phase offset adding section 212 adds variation amount $\cos \theta 1$ and variation amount $\sin \theta 2$ respectively to the I channel and Q channel of the digital baseband signal, and thereby adds the frequency offset and phase offset on each channel of the digital baseband signal assumed to occur in radio circuit 43 of transmission system 40. Delay adjusting section 213 adds a circuit delay amount assumed to occur in radio circuit 43.

Pseudo power amplifier (PA) section 214 is to generate simulated non-linear distortion assumed to occur in an amplifying section of radio circuit 43, and for example, is configured as shown in FIG.7. Pseudo PA section 214 calculates $\sqrt{(I^2+Q^2)}$ in envelop amplitude calculating section 230, and thereby calculates envelop amplitude X of the digital baseband signal to output to averaging circuit 231 and distortion calculating section 232.

Averaging circuit 231 averages the envelop

amplitude for a time corresponding to a forgetting factor (i.e. level calculation time constant) set by control apparatus 110, and outputs obtained average value Pave to saturation level computation circuit 233. Saturation

5 level computation circuit 233 obtains saturation level Asat in the following equation assuming the average value of envelop amplitude as Pave and backoff of the power amplifier set in control apparatus 110 as IBO.

$$A_{sat} = P_{ave} \times 10^{-\frac{IBO}{20}} \qquad \cdots\cdots (1)$$

10

Distortion computation section 232 calculates a control value of amplifier 234 in the following equation using the envelop amplitude value X obtained in envelop amplitude calculating circuit 230 and saturation level

15 Asat obtained in saturation level computation circuit 233.

$$\text{Control value} = \frac{1}{\left\{ 1 + \left(\frac{|x|}{A_{sat}} \right)^{10} \right\}^{\frac{1}{10}}} \qquad \cdots\cdots (2)$$

In this way, pseudo power amplifier (PA) section

20 214 is capable of adding simulated non-linear distortion assumed to occur in the amplifying section of radio circuit 43 to the digital baseband signal.

Reception analog adjusting section 202 is configured as shown in FIG.8. In reception analog

adjusting section 202, the digital baseband signal output from automatic gain control section 104 is input to frequency offset · phase offset adding section 251.

Frequency offset · phase offset adding section 251 performs the same processing as in frequency offset · phase offset adding section 212 of transmission analog adjusting section 201. In other words, the section 251 adds the frequency offset and phase offset assumed to occur in radio circuit 53 of reception circuit 50 to I and Q channels. Actually, frequency offset · phase offset adding section 251 is comprised of a complex multiplier which multiplies each channel signal by variation amount $\cos\theta 1'$ or $\sin\theta 2'$ respectively corresponding to instantaneous phase $\cos\theta 1'$ or $\sin\theta 2'$. In other words, the I channel signal is multiplied by variation amount $\cos\theta 1'$, while the Q channel signal is multiplied by variation amount $\sin\theta 2'$.

In obtaining instantaneous phases $\theta 1'$ and $\theta 2'$, reception analog adjusting section 202 calculates a phase rotation amount per sample from frequency offset set value S22B in phase increment calculating section 252 to output to mod 2π calculating circuits 254 and 256. At this point, to add deterioration in orthogonality between the I channel signal and Q channel signal, adder 255 adds orthogonality deterioration amount S22C to a phase rotation amount of the Q channel signal.

A phase of the last sample is input to adder 253.

The phase of the last sample is calculated by Z-1 calculating circuit 259 performing computation based on an initial phase (i.e. phase offset) S22A and the phase of the last sample. Adder 253 adds the phase rotation amount corresponding to one sample calculated in phase increment calculating circuit 252 to the phase of the last sample, and thereby obtains a phase rotation amount of a current sample.

Then, frequency offset · phase offset adding section 251 adds variation amount $\cos\theta 1'$ and variation amount $\sin\theta 2'$ respectively to the I channel and Q channel of the digital baseband signal, and thereby adds the frequency offset and phase offset on each channel of the digital baseband signal assumed to occur in radio circuit 53 of reception system 50.

Gain unbalance generating section 261 amplifies the I channel signal and Q channel signal of the digital baseband signal independently, and thereby generates a gain difference. DC offset adding section 262 increases or decreases each of the I and Q channels by a constant value, and thereby adds the DC offset. Delay adjusting section 263 adds a circuit delay amount assumed to occur in radio circuit 53.

A user is capable of selecting arbitrarily via control apparatus 110 various set values S20 (S20A to S20I) and S22 (S22A to S22H) of transmission analog adjusting section 201 and reception analog adjusting

section 202, as well as other set values S1, S4, S10, S11 and S12.

Thus, it is possible to simulate gain unbalance, DC offset, frequency offset, phase offset, circuit delay, non-linear distortion in amplification, or the like assumed to occur in radio circuits 43 and 53, prior to completion of radio circuit 43 of transmission system 40 and radio circuit 53 of reception system 50, i.e. at the stage where digital BB processing sections 41 and 51 have only been completed. It is thereby possible to evaluate characteristics of digital BB processing sections 41 and 51 in combining digital BB processing sections 41 and 51 under development and radio circuits 43 and 53 with various characteristics.

According to the aforementioned configuration, in addition to the configuration of Embodiment 1, transmission analog adjusting section 201 and reception analog adjusting section 202 are provided, where the section 201 simulates signal deterioration in radio circuit 43 of transmission system 40 by digital processing, while the section 202 simulates signal deterioration in radio circuit 53 of reception system 50 by digital processing. It is thus possible to implement channel simulator 200 enabling further detailed evaluations of characteristics of the digital baseband processing sections prior to completion of development of radio circuits 43 and 53.

(Other Embodiment)

In addition, in the aforementioned Embodiments, as shown in FIG.2, in simulating characteristics on a single-path channel, the case is described where by adding,

5 to a digital baseband signal, noise of a level corresponding to a level obtained by dividing a noise level by a fading variation value, receiver noise simulating the SNR variation due to fading is added with the signal level of a digital baseband signal kept constant.

10 However, a configuration to implement the present invention is not limited to that as shown in FIG.2.

Described below is an example of another configuration to add receiver noise simulating the SNR variation due to fading, while keeping the signal level

15 of a digital baseband signal constant.

FIG.9 illustrates a model of how to add receiver noise on a single-path channel described in Embodiment 1 as described above. FIG.10 illustrates an example of another configuration. Receiver noise adding means in

20 FIG.10 adds a level variation due to fading to an input signal by multiplier 301 as fading variation adding means. Further, adder 302 adds noise as noise adding means. A level of the signal provided with fading and noise by amplifier 303 and AGC section 304 as gain adjusting means

25 is adjusted using a gain that is the reciprocal of the fading variation value. By this means, as in Embodiment 1, it is possible to add receiver noise simulating the

SNR variation due to fading while keeping the signal level of a digital baseband signal constant. In other words, it is possible to obtain an output signal as shown in FIG.4(C). In addition, an output of amplifier 303 is

5   not returned to AGC section 304 in the example in FIG.10, but such feedback may be carried out.

The present invention is not limited to the aforementioned Embodiments, and is capable of being carried into practice with various modifications thereof.

10 A channel simulator according to an aspect of the present invention is a channel simulator to evaluate characteristics on a single-path channel of a wireless apparatus that is a development apparatus, and adopts a configuration provided with an input section that inputs

15 an output signal of a digital baseband processing section provided in a transmission system of the development apparatus, and a receiver noise adding section that adds receiver noise simulating the SNR variation due to fading to the signal input via the input section , while keeping

20 an entire signal level constant.

According to this configuration, the digital baseband signal is directly input from the input section, and therefore, performance deterioration does not occur due to an analog circuit. Then, using the receiver noise

25 adding section, only the SNR variation due to fading is added as a noise level variation, without adding any variation to the signal. It is thereby possible to

measure characteristics of the case where AGC and AFC ideally operates, and to compare with theoretical characteristics or computer simulation results to study. As a result, it is possible to evaluate performance of

5   the digital baseband processing section using only a digital baseband signal without an AGC circuit and AFC circuit, and to improve efficiency in development of the wireless apparatus.

      A channel simulator according to an aspect of the

10   present invention adopts a configuration where noise of a level corresponding to a level obtained by dividing a noise level by a fading variation value to the signal input via the input section.

      A channel simulator according to an aspect of the

15   present invention adopts a configuration provided with a fading variation adding section that adds a level variation due to fading to the signal input via the input section, a noise adding section that adds noise to the signal input via the input section, and a gain adjusting

20   section that adjusts a level of the signal given fading and noise by the fading variation adding section and the noise adding section, using a gain that is the reciprocal of the fading variation value.

      According to these configurations, it is possible

25   to excellently execute the processing for adding, to the digital baseband signal, a noise level simulating the SNR variation due to fading, while keeping the entire

signal level constant.

A channel simulator according to an aspect of the present invention is a channel simulator to evaluate characteristics on a multipath channel of a wireless apparatus that is a development apparatus, and adopts a configuration provided with an input section that inputs an output signal of a digital baseband processing section of a transmission system of the development apparatus, a multipath signal forming section that forms a signal corresponding to a signal of each path from the signal input via the input section, a fading variation adding section that adds only a level variation due to fading to the signal of each path of a multipath signal, an adding section that adds the signal of each path given a fading variation, a receiver noise adding section that adds receiver noise to an added signal obtained in the adding section, and a gain control section that performs gain control such that a level of the signal provided with the receiver noise is constant.

According to this configuration, the digital baseband signal is directly input from the input section, the fading variation adding section adds only the level variation due to fading to the signal of each path, the gain control section makes a level correction so as not to loose a bit in AD conversion in the reception system of the development apparatus after adding the receiver noise, and it is thereby possible to measure

characteristics of the time AFC and AGC almost ideally operates on each path even when a radio circuit of the reception system of the development apparatus is not present. As a result, it is possible to evaluate

5 performance of the digital baseband processing section only using a digital baseband signal without the AGC circuit and AFC circuit. It thus becomes possible to evaluate characteristics of the digital baseband processing section without the radio circuit, thereby

10 enabling improved efficiency in development.

A channel simulator according to an aspect of the present invention adopts a configuration further provided with a second input section that inputs an output signal from an analog baseband processing section provided

15 subsequent to the digital baseband processing section of the development apparatus, and an analog baseband processing section that converts an analog baseband signal input from the second input section into a digital baseband signal, where the receiver noise adding section

20 adds the receiver noise component to the digital baseband signal obtained in the analog baseband processing section.

A channel simulator according to an aspect of the present invention adopts a configuration further provided

25 with a second input section that inputs an output signal from an analog baseband processing section provided subsequent to the digital baseband processing of the

development apparatus, and an analog baseband processing section that converts an analog baseband signal input from the second input section into a digital baseband signal, where the multipath signal forming section forms

5   a multipath signal from the digital baseband signal obtained in the analog baseband processing section.

According to these configurations, it is possible to evaluate characteristics in a combination of the digital baseband processing section and the analog

10 baseband processing section. It is thus possible to evaluate performance of the time the analog baseband processing section becomes operable, in addition to the digital baseband processing section.

A channel simulator according to an aspect of the

15 present invention adopts a configuration further provided with an analog adjusting section that is comprised of a digital circuit and that adds a noise component simulating signal deterioration in a radio circuit of the development apparatus to the digital baseband signal,

20 corresponding to an input set value.

According to this configuration, in evaluating performance of the digital baseband processing section at the stage where development of the radio circuit is not completed, it is possible to carry out performance

25 evaluations in consideration of signal deterioration in the radio circuit, and it becomes possible to further specifically evaluate characteristics of the digital

baseband processing section prior to completion of development of the radio circuit.

A wireless apparatus evaluation method of an aspect of the present invention is a method of evaluating a
5 wireless apparatus to evaluate performance on a single-path channel of the wireless apparatus that is a development apparatus, where receiver noise simulating the SNR variation due to fading is added to a digital baseband signal of the wireless apparatus with a level
10 of the signal kept constant, and performance on the single-path channel of the wireless apparatus is evaluated based on the signal provided with the receiver noise.

A wireless apparatus evaluation method of an aspect
15 of the present invention is a method of evaluating a wireless apparatus to evaluate characteristics on a multipath channel of the wireless apparatus that is a development apparatus, where a multipath signal is formed from a digital baseband signal of the wireless apparatus,
20 a signal of each path of the multipath signal is given the fading variation simulating a level variation due to fading, the signal of each path given the fading variation is added, receiver noise is added to an added signal, gain control is performed on the signal provided
25 with the receiver noise so that a level of the signal is constant, and performance on the multipath channel of the wireless apparatus is evaluated based on the signal

subjected to gain control.

According to these methods, it is possible to evaluate channel characteristics of a digital baseband processing section using only a digital baseband signal

5   without an AGC circuit and AFC circuit, i.e. without a radio circuit, and it is thereby possible to improve efficiency in development of the wireless apparatus.

As described above, according to the present invention, an output signal of the digital baseband

10   processing section is directly input, receiver noise simulating the SNR variation due to fading is added with the entire signal level kept constant in single-path channel simulation, while respective signals of paths are provided with only amplitude variations due to fading

15   to be combined with a level of the path-combined signal kept constant in multipath channel simulation. It is thereby possible to evaluate performance of the digital baseband processing section without waiting for development of a radio circuit. As a result, it is

20   possible to improve efficiency in development of wireless apparatuses.

This application is based on the Japanese Patent Application No.2002-372792 filed on December 24, 2002, entire content of which is expressly incorporated by

25   reference herein.

Industrial Applicability

The present invention is suitable for use in developing, for example, a cellular telephone, base station of the cellular telephone, and MT (Mobile Terminal) and AP (Access Point) of wireless LAN (Local Area Network).